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OVERVIEW

During the reporting period, we continued our development and supporting research for the MODIS BRDF-Albedo and Land Cover/Land Cover Change products. This work included modeling, validation, and empirical studies involving data analysis, as well as the preparation of revisions to draft Algorithm Technical Basis Documents (ATBDs) as required by the EOS Project. We further presented and defended our ATBD's at the Review Panel Session during May.

TASK PROGRESS

BRDF/Albedo Product

Model Development

Although much of our effort during the 6-month reporting period was directed toward the continued development of the BRDF ATBD, we were still able to continue with model development. Here our efforts were focused on the semiempirical model approach to describing the BRDF. In this approach, the shape of the directional reflectance function for a surface is modeled as the weighted sum of two simple trigonometric functions of view and illumination positions and a constant. The constant and function weights are fitted to the directional observations by a least squares technique implemented by the Powell algorithm. The trig functions are attributed to (1) volume scattering and (2) surface scattering, and have a physical basis derived from simplification of physical theory. Actually, there are several candidate functions for each type (volume and surface scattering), so a number of semiempirical models are possible. A more complete description appears in the BRDF/Albedo ATBD.

We also continued development of the Monte Carlo surface BRDF model and the stochastic BRDF model. The former models the BRDF of a heterogeneous mixed pixel with topographic relief, and the latter models the influence of the atmosphere on the BRDF of a surface composed of three-dimensional envelopes of scattering media. Both of these efforts are directed toward the understanding of the spatial aggregation problem of land surface covers as it applies to BRDF. These models are being developed primarily by Shunlin Liang at GSFC; although no longer affiliated with BU, Dr.

Liang continues to participate in MODIS research at a reduced level of activity.

Model Validation

Validation efforts focused on two modeling approaches: semiempirical models and our geometric-optical mutual shadowing model. For the semiempirical models, we examined the fit to directional reflectance measurements in red and NIR bands made on eleven surface types including soils, crops, forests and grasslands. For each surface type, three or four sets of measurements at different solar zenith angles were available. The models fit the measurements very well, with RMS errors often less than 5% of mean reflectance values.

In collaboration with USAF Phillips Laboratory, we continued the construction of a distributed-parameter BRDF database for the Stanislaus National Forest for the purpose of albedo simulation. The database characterizes the geometric-optical characteristics of the vegetation cover of each 30-m pixel and calculates the albedo of the scene as a whole, using the terrain-dependent version of the mutual shadowing BRDF model. The solar spectrum albedo for the entire diverse scene is quite conservative, varying only by $\pm 10\%$ or so with different sun angles. This suggests that albedo generalizes well over large regions, which is an important conclusion for climatic modelers as well as for the preparation of our BRDF/Albedo product. The major variable influencing albedo is the nature of the surface cover, not the sun angle. We continued work on the manuscript describing these results, but at the close of the reporting period the manuscript was still unfinished.

Algorithm Development

We also completed the development of the first version of the specific algorithm to be used to recover BRDF and albedo from MODIS and MISR data. The algorithm selects one of five candidate models to describe the BRDF: (1) a topographic model, driven by high-resolution digital terrain data; (2) a topographic model driven by a statistical characterization of slope facets; (3) a plane-parallel vegetation canopy model; (4) a geometric-optical model; and (5) an empirical model with physically-derived kernels that describe the shape of the BRDF function without providing specific physical parameters. The BRDF algorithm uses the Powell algorithm to fit the specific model to the observations in a forward, iterative procedure. The software was delivered to the MODIS SDST in late January.

With the arrival of Dr. Wolfgang Wanner from the University of Kiel, we began the development of a new structure for the BRDF code that is much more flexible, allowing BRDF models to be freely added at will. With the new code, it will be much easier to compare different models with data in both forward and inverse modes. This new version will provide the basis for our delivery of the next version of the code, due in October.

Algorithm Technical Basis Document

During the reporting period, we continued the development of the BRDF/Albedo product ATBD, which required a major expenditure of effort. Version 2.1 was completed and submitted to EOS Chief Scientist Mike King on March 1 as directed by the EOS Project.

In early May of the reporting period, we attended the ATBD review panel sessions, held near GSFC. We presented our Albedo/BRDF Algorithm and defended it before the panel. We also attended the ATBD presentations of the CERES and MISR instruments, which were very helpful in understanding the synergism between MODIS, MISR, and CERES.

Land Cover/Land-Cover Change Products

Land Cover

During the reporting period, we continued our studies of the effects of resolution cell size on the distribution of land cover units. Previously, we had shown that estimates of the proportions of land cover types vary as a function of spatial resolution, with large changes occurring as aggregation becomes coarser and coarser. The changes are influenced by the initial coverage of each land cover class as related to that of other classes, and to the spatial pattern of occurrence (e.g., patch size and shape) of the class. The target area for the study is the Plumas National Forest in the Sierra Nevada of California. Our current work uses linear regression and regression-tree models to predict cover class proportions using patch size, scale of aggregation, and the Shannon diversity index. A manuscript summarizing the results of this modeling work was nearly ready for submission to Landscape Ecology at the close of the period.

Our work on the use of neural net classifiers for the land cover product also continued. We began the application of a neural net classifier to TM data for the Plumas National Forest. These data were resampled to 250 m and 500 m spatial resolution, using the convolution algorithm provided by the MODIS SCST. The classifier performed quite well in separating the broad classes of land covers that are planned to be recognized in the final product. The classifier performed poorly, however, when exercised on composited NDVI data of the same area. The results seem to indicate that at the local scale of a small region, there is not much information in NDVI time trajectories; rather, that type of information is much more useful at the subcontinental or continental scale. However, the cover classes within a small region can be accurately distinguished using the spectral resolution that is lost in the conversion of measurements to composited NDVI.

We also implemented the Running and Nemani land cover logic, which uses a hierarchical decision tree classifier on composited NDVI

and surface temperature data, as applied to the Plumas National Forest. We compared the neural net and decision-tree approaches to classification in the specific context of the Plumas. The Running-Nemani approach provided accuracies at about the 60 percent level, which we considered unacceptable for the land-cover product. However, the Plumas is atypical in some respects, as the number of land cover types is quite limited and the ground truth is a dataset collected for timber inventory, not land cover. A report on this research was in rough draft at the close of the period. It will be refined over the summer, and will either become a technical report or be submitted for journal publication.

The neural net analysis worked with the multiresolution simulated MODIS data derived from TM. It used a single date, so it tested the ability of MODIS bands and resolutions to discriminate land covers without temporal information. Classification accuracy was about the same as for the Running-Nemani AVHRR application. However, at MODIS scales, nearly all pixels are mixtures of land cover types. If this fact is acknowledged and we accept as correct a label that could apply to either of the two leading land cover classes within a large pixel, the accuracies are about 80 percent, which is within the range of acceptability. Further, the neural net outputs seem to respond to the proportions of land cover types within mixed pixels, allowing the possibility of mixed labels such as grass/brush, brush/grass, conifer forest/brush, brush/conifer forest, etc. These would more accurately reflect the composition of each pixel and allow collection of more relevant accuracy statistics. A manuscript summarizing this work was nearing completion at the close of the reporting period.

Land-Cover Change

In late May, the Principal Investigator traveled to Ispra, Italy, (see Other Activities Section) and met with Eric Lambin. Dr. Lambin showed work on GAC classifications of land cover change in Africa over a ten year period, analyzing separately-composited NDVI and surface temperature data within one-month periods. Preliminary results show that principal components of these data sort change vectors rather well, and the continental pattern of change components agrees fairly well with progressive changes occurring within the period. This research validates the approach to the land-cover change product (post-launch) that we plan for higher-resolution MODIS data.

Algorithm Development

A considerable effort during this period was devoted to the redrafting of the Land Cover/Land-Cover Change Product ATBD. Version 2.0 of the ATBD was prepared and submitted on March 1, as requested by the EOS Project. It was further presented and defended at the ATBD review panel meeting in early May.

As a prototype algorithm, we delivered a trained neural net with input images and output classification to the MODIS SDST.

ANTICIPATED ACTIVITIES DURING THE NEXT QUARTER

BRDF/Albedo Product

Our primary activities during the next quarter for the BRDF/Albedo product will be to continue to develop, refine and test the BRDF/Albedo algorithm. In this development, we will stress (1) the continuing development of well-compartmented and documented code for both forward modeling and inversion of any of a suite of models; and (2) the implementation and testing of the fitting of semiempirical models as a first line BRDF product that will allow correction of directional reflectance and calculation of albedo.

Land Cover/Land-Cover Change Product

During the next quarter, we plan to complete our analyses of the Plumas test site and move to a new and larger region. For this phase of algorithm development and testing, we will use the state of California. We have obtained the digital Cal-Veg map, which mapped the land covers of California using Landsat MSS data in the early 1980's. Although there have been changes in land cover since that time, the Cal-Veg map is at a 1-km resolution and contains units that are much closer to those of Running that we plan for the MODIS Land Cover product. We have also obtained a revised version of the Running-Nemani classification logic, and will test that as well. For Land-Cover Change, we will keep apprised of Eric Lambin's work at ISPRA and its implications for the MODIS product.

PROBLEMS/CORRECTIVE ACTIONS

During this reporting period, we did not encounter any significant problems requiring corrective actions beyond the every day problems that occur in research and algorithm development.

OTHER ACTIVITIES

1. Dr. Wolfgang Wanner, of the University of Kiel, joined the BRDF research team on February 1. Dr. Wanner's prior research was in space physics and concerned interplanetary fields of matter and energy in the solar system.

2. Dr. Eric Lambin, formerly Assistant Professor of Geography at Boston University, continued research at the EU Joint Research Center in Ispra, Italy, focused on land cover change. Although no longer supported by our MODIS budget, this work continues to be of direct relevance. Dr. Lambin was proposed as an Associate Team Member, and his appointment was approved by Team Leader Vince Salomonson.

3. Two new first-year graduate students, Jordan Borak and Paul Fisher, began work on the land cover product in January, providing support for Aaron Moody.

4. The Principal Investigator attended the Sixth International Symposium on Physical Measures and Signatures in Remote Sensing and presented a paper summarizing recent work in BRDF modeling. The symposium was held in Val d'Isere, France, January 17-21, 1994.

5. The Principal Investigator attended an informal meeting at GSFC on February 1 which focused on BRDF and VI issues and presented plans for BRDF retrieval from MODIS and MISR as included in the ATBD.

6. On Tuesday, March 15, Tom Pagano and Carl Schueler of Santa Barbara Research visited BU and were briefed on the status of the BRDF/Albedo and Land Cover products by the BU research staff.

7. The Principal Investigator attended the Annual Meeting of the Association of American Geographers during the period March 29-April 2, presenting a paper on the MODIS instrument and the land products to be derived from it. The meeting was held in San Francisco.

8. The Principal Investigator attended the first day of the MISR Team Meeting at the Jet Propulsion Laboratory in Pasadena, on Wednesday, March 30.

9. The Principal Investigator and other members of the BU research team attended the MODIS Team Meeting, ATBD Review Meeting, and MODIS Land Team Meeting during the period May 4-12. Attendees included Alan Strahler, Wolfgang Wanner, Xiaowen Li and Aaron Moody. Crystal Schaaf, of the Air Force Geophysics Lab, whose research has been coordinated with that of the MODIS BRDF/Albedo Product, also attended.

10. The Principal Investigator attended a meeting of the IGBP-DIS Working Group on Land Cover Validation in Ispra, Italy, on May 16-17. The working group's objective is to plan a validation procedure for the IGBP-DIS 1-km Land Cover Map, to be produced from the global composited 1-km AVHRR dataset now in the final stages of assembly at EROS Data Center. The working group's activities are clearly germane to both the preparation of the Land Cover product and its validation.

PUBLICATIONS

The status of pending publications supported all or in part by this contract and its predecessor is shown below.

Submitted

The following manuscripts were submitted for publication during this reporting period:

Strahler, A. H., 1995, Vegetation canopy reflectance modeling -- Recent developments and remote sensing perspectives, submitted for journal publication through the Proceedings of the Sixth International Symposium on Physical Measurements and Signatures in Remote Sensing.

Previously Submitted

The following manuscripts were previously submitted and are in the review process:

Li, X., A. H. Strahler, and C. E. Woodcock, 1994, A hybrid geometric optical-radiative transfer approach for modeling albedo and directional reflectance of discontinuous canopies, IEEE Trans. Geosci. and Remote Sens., submitted.

Liang, S. and A. H. Strahler, 1994, An analytic radiative transfer model for a coupled atmosphere and leaf canopy, J. Geophys. Res., submitted.

Liang, S. and A. H. Strahler, 1994, Retrieval of surface BRDF from multiangle remotely sensed data, IEEE Trans. Geosci. and Remote Sens., submitted.

Revised and Accepted

The following manuscripts were accepted for publication with revision, were revised, and resubmitted during this reporting period:

Schaaf, C. B., X. Li and A. H. Strahler, 1994, Topographic effects of bidirectional and hemispherical reflectances calculated with a geometric-optical canopy model, IEEE Trans. Geosci. and Remote Sens., in press.

Liang, S., and A. H. Strahler, 1994, A four-stream solution for atmospheric radiance transfer over a non-Lambertian surface, Applied Optics, in press.

Schaaf, C. B. and A. H. Strahler, 1994, Validation of bidirectional and hemispherical reflectances from a geometric-optical model using ASAS Imagery and Pyranometer Measurements of a Spruce Forest, Remote Sens. Environ., in press.

In Press

The following manuscripts were in press during this reporting period:

Moody, A., and C. E. Woodcock, 1994, Scale-dependent errors in the estimation of land-cover proportions--Implications for global land-cover datasets, Photogrammetric Engineering and Remote Sensing, in press.

Moody, A. and A. H. Strahler, 1994, Characteristics of composited AVHRR data and problems in their classification, Int. J. Remote Sens., in press.

Running, S., C. Justice, D. Hall, A. Huete, Y. Kaufmann, J-P. Muller, A. Strahler, V. Vanderbilt, Z-M. Wan, 1994, Terrestrial remote sensing science and algorithms planned for EOS/MODIS, Remote Sens. Environ., in press.

Lambin, E. F. and A. H. Strahler, 1994, Change-vector analysis: A tool to detect and categorize land-cover change processes using high temporal-resolution satellite data, Remote Sens. Environ., in press.

Lambin, E. F. and A. H. Strahler, 1994, Indicators of Land-Cover Change for Change-Vector Analysis in Multitemporal Space at Coarse Spatial Scales, Int. J. Remote Sens., in press.

Published (Copies provided under separate cover)

Schaaf, C. B. and A. H. Strahler, 1994, Simulating the bidirectional and hemispherical reflectance of mountainous and forested scenes with a geometric-optical model, Proc. Seventh Conf. on Satellite Meteorology, June 6-10, Monterey, CA (American Meteorological Soc.), pp. 602-604.

Jupp, D. L. B., E. R. McDonald, B. A. Harrison, X. Li, A. Strahler, and C.E. Woodcock, 1994, Prospects for Mapping Canopy Structure using Geometric-Optical Models, Proc. 7th Australasian Remote Sensing Conference, Melbourne, Australia, March 1-4, 9 pp.

Abuelgasim, A. A. and A. H. Strahler, 1994, Modeling bidirectional radiance measurements collected by the Advanced Solid-State Array Spectroradiometer (ASAS) over Oregon Transect conifer forests, Remote Sens. of Environ., vol. 47, pp. 261-275.

Barnsley, M. J., A. H. Strahler, K. P. Morris, and J.-P. Muller, 1994, Sampling the surface bidirectional reflectance distribution function (BRDF): Evaluation of current and future satellite sensors, Remote Sensing Reviews, vol. 8, pp. 271-311.